ME-82-01

Deterioration of Bridge Substructures– Phase II

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Published by:
The Policy Planning and Research Division
Ontario Ministry of Transportation and Communications
Hon. James W. Snow, Minister
H.F. Gilbert, Deputy Minister

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January 1982

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1/ BACKGROUND

A preliminary report on the deterioration of bridge substructures was completed in January 1980 (1). The report discussed the nature and extent of deterioration at a number of sites. The investigation concluded that substructure deterioration resulting from exposure to salt splash and roadway drainage was not a widespread problem at the time of investigation, but repairs requiring significant expenditures would be necessary in the future. The report recommended that a policy of positive protection of substructures in new designs be developed and that alternative methods of repair be investigated and their performance monitored.

This report examines the effectiveness of a number of repair methods. Additional areas of research are suggested. Some of the sites included in this study were not part of the original investigation.

2/ EXTENT OF WORK

Table 1 lists the sites tested in this phase. Of the original nine test locations seven have been retested. Five structures were repaired and the repairs monitored. Two structures (viz. Hwy. 76 U.P., and Bridge 21 - Hwy. 427/401) were not repaired, but were monitored to assess any changes in condition. One additional site (viz. Bissette Creek) was added to the survey after it was repaired.

3/ TEST PROCEDURES

During the 1979 survey the elements listed in Table I were tested as follows:

- o Measurement of Half-Cell potentials (ASTM C876-77)
- o Pachometer Survey
- o Delamination Survey
- o Selective coring to measure chloride ion content - contents are reported as % chloride ion by mass of concrete (2)

During subsequent testing, the following tests were carried out:

- o Measurement of Half-Cell potentials (ASTM C876-77). Note: all potentials measured in relation to the copper-copper sulphate half-cell.
- o Delamination Survey
- o Visual Inspection

4/ RESULTS

Table II lists the repair techniques used on each structure.
Table III lists the testing history for each structure.

4.1/ Structures not Repaired

4.1.1/ Hwy. 76 U.P.

Hwy. 76 U.P. demonstrates the deterioration of columns exposed to salt splash. In 1979 the area of delamination on the southeast and southwest columns were 10% and 50% respectively (Figure 1). Two additional winters of exposure have increased the delaminated areas to 18% and 75% respectively (Figure 2). Half-cell readings were taken in accordance with ASTM C876-77 which defines those readings numerically less than -0.20 V CSE as indicating a greater than 90% probability that no reinforcing steel corrosion is occurring. Those readings in the range of -0.20 to -0.35 V CSE indicate that corrosion activity is uncertain. Readings numerically greater than -0.35 V CSE indicate a greater than 90% probability that reinforcing steel corrosion is occurring.

The percentage of half-cell readings at Hwy. 76 U.P. within the high probability of corrosion range has increased on the southwest column. In 1979, 35.5% of the readings were more negative than - 0.35 V. In 1981 the percentage had risen to 52.1%. It can be assumed that the percentage will continue to increase as corrosion continues. The southwest column receives the greatest amount of salt splash because it is closest to oncoming traffic. The southeast column had a similar increase in delaminated area, and a similar change in half-cell readings $\leq$-0.35 V. The middle column has shown little change in the two-year period. All of the half-cell readings are $>$-0.35 V. Readings $\geq$-0.25 V indicate a high probability that no reinforcing steel corrosion is occurring in the area at the time of measurement. This column also has no delamination.

These results may indicate that exposure to the elements plays a major role in the deterioration of the columns. The three columns receive salt splash from adjacent traffic. However, the outside columns, southeast and southwest, also receive direct exposure to rainfall.

4.1.2/ Bridge 21, Hwy. 427/401

In 1979 the east abutment of Bridge 21 exhibited extremely high half-cell readings (52.4% <-0.51 V). This figure increased in 1981 to 76.9%. The abutment does not exhibit any physical deterioration such as spalling, cracking or delamination. Chloride tests indicate high content in the outer 20 mm (average 0.461%), while the content at the level of the steel (80 to 100 mm) is 0.054%. Steel removed in the test cores did not indicate any rusting or corrosion. As this is not conclusive, further work is necessary to discover the reasons for the inordinately high half-cell readings. Corrosion may be occurring on the back side of the abutment although coring into the abutment to a depth of 780 mm has shown chloride contents in the order of 0.077% soluble chloride.

4.2/ Structures Repaired

Six structures were repaired (viz. Bissette Creek, Burlington Skyway, County Rd. 46, Willey Sideroad, Hwy. 2/401 O.P. and Gardiner Expressway.)

The structures are discussed in terms of the four materials used for repair:

- o Portland cement-based grout with an expansion admixture -- In-Pakt grout (Bissette Creek).
- o Fast setting magnesium phosphate based concrete - Set 45 (Burlington Skyway).
- o Portland cement concrete (County Rd. 46, Willey Sideroad, Burlington Skyway).
- o Latex modified shotcrete (Hwy. 2/401 O.P., Gardiner Expressway).

4.2.1/ In-Pakt Grout

The Bissette Creek columns were repaired in 1979. Delaminations were removed using an air hammer and hand chipping. The steel was wire brushed to remove rust and scale. The columns were formed with plywood and bound

by wire straps. The grout was pumped into place using a hand operated pump. After curing, the forms were removed leaving a smooth, well bonded repair (Figure 3). In total, 15% of the column was patched. Half-cell testing showed 24% of the readings <-0.35 V; 51% of the readings lie in the -0.25 V to -0.35 V range. No comparison to pre-repair status is possible because the site was not tested initially.

A significant drop in the half-cell readings was found in the area of the patch. Figure 4 illustrates the half-cell readings in the patch area and adjacent area. The lower readings in patch areas could be due to the grout being slightly dielectric. Further testing is necessary to define the effect this material may have on half-cell test reliability.

The delaminated area (3%) may be delaminations missed during the chipping of the column at the time of repair or the delaminations may have developed since the repair. The half-cell readings indicate active corrosion which may be responsible for the deterioration. Further monitoring is necessary to assess the development of additional delaminations.

4.2.2/ Fast Setting Magnesium - Phosphate Based Concrete - Set 45

Column S-12 at the Burlington Skyway was repaired using Set 45. During the removal of the delaminations 50% were missed by the repair crew. This was probably due to the crew's lack of experience in detecting delaminations. The exposed area was covered with Set 45 using a number of thin layers placed over a period of days.

After one winter (1979-80) the patch area was 40% delaminated (Figure 5). The percentage of half-cell readings <-0.35 V increased from 55.6% to 68.5%. Twelve months after repair, 2% of the patch area was spalled. Nineteen months after repair, 10% of the patch was spalled and the percentage of half-cell readings <-0.35 V had increased to 75.6%.

A number of factors contributed to the failure of the patch:

- o Not all of the delaminations were found and removed during the initial work.

- o The reinforcing steel was not sand blasted to clean metal.

- o The column continued to be exposed to salt laden run-off from leaking expansion joints overhead and deck drains which discharge adjacent to the column.

- o The layering of repair material may have resulted in poor bonds between layers allowing the ingress of water and subsequent freeze-thaw action.

The patch was subsequently removed and replaced by another material. (See 4.2.3).

4.2.3/ Portland Cement Concrete

Three sites were repaired using Portland cement concrete (viz. Burlington Skyway, County Rd. 46 and Willey Sideroad). At each site, the delaminations were removed with an air hammer and hand chipping; the steel was sand blasted to white metal, and the column was formed. The concrete was placed and vibrated externally.

Column S-12, referred to in 4.2.2, was repaired a second time. After the Set 45 patch failed, the patched area and adjacent delaminations were removed with an air hammer. The steel was sand blasted and coated with red lead primer. The primer was used as a rust inhibitor in case there was a delay between sand blasting and the placing of the patch material. The primer was not used as an insulator or as a coating to prevent corrosion after patching.

Form ties were anchored into the sound concrete so that forms could be attached to the vertical face of the column. Once the forms were mounted, the Portland cement concrete was poured into place. After curing, the forms were removed and the exposed form ties were cut-off at the surface. (Figure 6). The percentage of half-cell readings <-0.35 V dropped from a pre-repair high of 75.6% to 51.4%. This indicates that

corrosion is still occurring although not as actively as it was prior to the repair. The readings may have been influenced by the red lead primer. Laboratory tests will be carried out to investigate the influence of the red lead.

Column S-6 at the Burlington Skyway was repaired in a similar fashion, although the red lead was not applied to the sand blasted steel. Figures 7 and 8 show the column before and after repair. Half-cell readings indicate an increase in corrosion activity since the repair. The percentage of readings <-0.35 V has risen from 27.8% before repair to 46.9% immediately after repair, and 49.5% sixteen months after repair. The increase may be due to exposed reinforcing bars above the patched area (Figure 8). The bars were exposed during chipping, but the area was never patched. Only 4.5% of the column face was patched. The remainder of the column contains a corrosive environment with chloride levels ranging from 0.13% at the surface to 0.04% at the level of the steel reinforcement.

County Road 46 and Willey Sideroad O.P. are typical of bridges having round columns adjacent to a high volume freeway (Hwy. 401). Delaminations were removed and the steel sand blasted. Figures 9, 10 and 11 show the condition of County Rd. 46 before, during and after repair.

A custom fit steel form (Figure 10) was used to form the Portland cement concrete, and vibration was applied externally. Approximately 10% of the column was patched.

At County Road 46 the percentage of half-cell readings in the -0.20 V to -0.35 V range increased from 24.9% to 26.9% after repair. It should be noted that it is unusual to have phsyical distress occur where the CSE half-cell potentials are not <-0.36 V. Further study is necessary to clarify the reasons for this situation. The amount of cover may be a factor because there are less than 40 mm of clear cover in the distress area. There were no readings <-0.36 V before or after repair. Willey sideroad had an increase in the -0.20 V to -0.35 V range from 17.5% and 20% to 32.5% for each of the two columns tested. The percentage of readings <-0.36 V decreased from 12.5% and 17.5% to 5% on both columns.

These changes are likely due to the removal of the most severely corroded areas, while the remainder of the column continues to corrode.

4.2.4/ Latex Modified Shotcrete

Latex modified shotcrete was used to repair two sites: Bent 102 at the Gardiner Expressway and the abutments of the Hwy. 2 O.P. at Hwy. 401. In each case the delaminations were removed using an air hammer and hand chipping. The reinforcing steel was sand blasted to clean metal. Galvanized steel mesh, having a 50 mm spacing, was attached to the exposed reinforcing steel (Figure 12) and the shotcrete was applied. Both sites were sprayed with an acrylic sealer after the shotcrete was cured. Figures 13 and 14 show Bent 102 before and after repair. Figures 15 and 16 show the west abutment of Hwy. 2 O.P. before and after repair.

Both sites developed random hairline cracks within weeks of the repairs. The width and number of cracks do not appear to have changed since their initial appearance. Figure 17 shows the type of hairline cracking found at Bent 102.

Half-cell tests carried out at both sites gave questionable results. The galvanized wire mesh will cause the readings to have a larger negative value because zinc has a more negative potential than iron. Further testing is required to establish a correlation between the CSE half-cell potential and the corrosion activity of zinc in the presence of iron.

Both sites had a decrease in the percentage of readings <-0.36 V in the tests directly after repair. Hwy. 2 decreased from 88% to 83.7%. Bent 102 dropped from 47.8% to 36.1%, but has risen in the 18 months since repair to 51.2%. The high half-cell potentials may be due to the zinc half-cell effect or they may be due to increased corrosion activity in those areas not repaired.

Continued leaking of the expansion joints over Bent 102 and the abutments at Hwy. 2 will sustain a corrosive environment unless the acrylic sealers provide an effective barrier to the chloride laden run-off. The sealers used at both sites are designed to limit the ingress of chlorides and

moisture, not to act as waterproofing agents. Further testing will provide an indication of the effectiveness of these sealers.

4.3/ Technical Problems

A number of difficulties were encountered with the CSE half-cell during the two year study:

- o On all columns tested, with the exception of the Gardiner Expressway and the Burlington Skyway, the half-cell readings tend to decrease as the height above ground increases. In some cases the readings were almost 0.00 volts. A minimum value in the vicinity of -0.20 V would be expected for steel embedded in concrete. The low readings may be attributed to the columns being dielectric due to lack of moisture. The columns are protected from rainfall except on the outside exposure. The middle column at Hwy. 76 O.P. has 80.1% of its half-cell readings less than -0.20 V, yet receives a large amount of salt splash. It does not receive rainfall due to its sheltered location, nor does it receive run-off from the road above.

- o The marked decrease in half-cell values at Bissette Creek raises a question about the conductivity of the In-Pakt grout, and the validity of the test results. Within the patch area, 98% of the readings are less than -0.20 V.

- o The validity of the half-cell readings taken on Bent 102 and on Hwy. 2 is questionable due to the influence of the zinc half-cell. As a result of these difficulties, two Research Projects were initiated. Project 22120 looks at the electrical impedance of concrete and develops a method to measure corrosion current in the field. The project appears to have a lot of promise in the development of a corrosion current measurement technique which could be used where CSE half-cell testing is questionable. Project 22118 is a demonstration project designed to test various types of repair strategies.

5/ DISCUSSION

Four types of material were used to patch deteriorated areas. Test results show that after repair, there is little or no decline in the half-cell potentials within the patch area. Where there is a decline, it occurs where the percentage of readings $\leq$-0.35 V declines, and the percentage of readings between -0.20 V and -0.35 V increases. This indicates an uncertainty regarding the effectiveness of the repair techniques. The half-cell potentials in the unpatched areas have generally become more negative, indicating an increase in corrosion activity. This raises the concern that additional repair work will be necessary in the future. Due to the uncertainty of the half-cell test results, the use of In-Pakt grout and latex modified shotcrete cannot be accurately assessed.

Surface preparation is critical to the durability of the patch area. As stated earlier, the failure of the initial patch on Column S-12 of the Burlington Skyway was partially due to missed delaminations. The procedure of sand blasting the exposed reinforcing steel, as used in bridge deck repairs, is necessary to ensure that corrosion products are removed from the steel. The lack of clean steel may have contributed to the failure of the initial patch on Column S-12.

Isolated repairs to delaminated areas do not change the corrosive environments existing in sound concrete adjacent to the patches. The concrete will still receive salt splash from adjacent roads, leaking expansion joints, or open deck drains. These sources of corrosion inducing chlorides should be examined when condition surveys are carried out. The failure to repair leaking expansion joints at Highway 2/401 and the Gardiner Expressway may lead to additional deterioration in both the sound concrete and patched areas.

The present practice of visual inspections precludes the identification of those structures which are in distress but do not have any visible deterioration. Areas of high chloride content and low cover cannot be assessed visually. Delaminations can only be detected by physically testing the concrete. Sounding of the concrete during inspections would improve the detection of deteriorated members prior to the development of cracks and spalls.

6/ CONCLUSIONS

The need for detection and repair of substructure deterioration has been visibly demonstrated at sites such as the Gardiner Expressway. The results of lack of repair can be seen at the Hwy. 76 O.P. and Burlington Skyway. As indicated in the initial report (1), significant expenditures will be required in the near future to detect and repair substructure deterioration.

There is a need to develop new detection and repair strategies with which to maintain the existing structures. Training repair crews to detect delaminations in substructure components will assist them in detecting all existing delaminations and ensure that patch failure and secondary repairs are minimized.

The problem of leaking expansion joints at many locations will continue to create corrosive environments leading to increased deterioration in substructure components and additional repairs.

7/ RECOMMENDATIONS

1/ Those structures which have been repaired should continue to be monitored to assess the effectiveness and durability of the repairs.

2/ Techniques for testing repairs that cannot be accurately tested with the present CSE half-cell should be developed and field tested.

3/ Repair crews should be instructed in delamination detection techniques to ensure the identification of all existing delaminations.

4/ Techniques for the repair and rehabilitation of leaking expansion joints should be assessed with the intent of keeping chloride laden run-off away from substructure components.

5/ Alternative methods of repair should be investigated and demonstration projects undertaken. The repair methods should include cathodic protection, preplaced aggregate concrete, shotcrete with calcium nitrate added to inhibit corrosion, and alternative methods of steel preparation after sand blasting.

6/ Sealers such as those used on Hwy. 2/401 should be tested to assess their capabilities in preventing the ingress of chlorides and moisture.

8/ REFERENCES

[1] Manning, D.G. and Holt, F.B., Deterioration of Bridge Substructures - Phase I, January, 1980.

[2] Clear, K.C. and Harrigan, E.T., Sampling and Testing for Chloride Ion in Concrete, F.H.W.A-RD-77-85, Federal Highway Administration, August, 1977.

Table 1/ Details of Sites Investigated

Site #	Structure	Hwy.	Year Built	Repair	Elements Investigated
05123	Highway 76 U.P.	401	1964	-	3 S. Columns
37816	Bridge 21	401/ 427 IC	1968	-	East Abutment
29003	Bissette Creek Br.	17	1961	09/79	1 E. Column
36060	Burlington Skyway	QEW	1957	06/80	Columns S6, S12
05047	Willey Sideroad V.P.	401	1967	06/81	2 S. Columns
33177	County Rd. 46 V.P.	401	1959	09/80	1 S. Column
23173	Hwy. 2 O.P. IC 31	401	1955	07/81	West Abutment
-	Gardiner Expressway	QEW	1959	09/79	Pier Bent 102

Table 2/ Repair Details

Site	Test Area	Repair Date	Material Used	Delaminations	Sand Blasting	Steel Preparation	Other Details
Bissette Creek Hwy 17 #29003	1 of 2 East Columns	09/79	In-Pakt Grout Mixed on Site	Removed with air hammer and hand chipping	None. Steel was wire brushed	None	Column Formed with Plywood and wrapped with steel bands. Grout pumped into place. After curing, forms removed
Burlington Skyway/QEW #36060	Column S-12 West Face-West Column	05/80	Set-45 Hand Mixed on site	Removed with air hammer. 50% of delaminations left in place	None	None	Set 45 layered in place with hand trowel over a period of days
		06/81	Portland cement Concrete 3:1 mix. Mixed with small mixer on site	Old Patch 80% delaminated. Patch and missed delaminations removed with air hammer and hand chipping.	Steel sand blasted to white metal	Steel painted with red lead primer	Form bolted to column face. Concrete poured in place. External vibration.
	Column S-6 North Face-East Column	06/80	Portland cement concrete 3:1 mixed on site with small mixer	All delaminations removed with air hammer	Steel sand blasted to white metal	None	Steel form strapped to column. Concrete poured in place. External vibration.
County Road 46 U.P./Hwy. 401 #33177	South West Column	09/80	Portland cement concrete mixed on site with small mixer.	All delaminations removed with air hammer	Steel sand blasted to white metal	None	Steel form strapped to column. Concrete poured in place. External vibration.
Willey Sideroad U.P./Hwy. 401 # 05047	2 of 3 South Columns	06/81	Portland cement concrete mixed on site with small mixer.	All delaminations removed with air hammer	Steel sand blasted to white metal	None	Steel form strapped to column. Concrete poured in place. External vibration.
Hwy 2 OP/Hwy 401 Int. 31 # 23173	West Abutment	07/81	Latex modified shotcrete reinforced with galvanized wire mesh.	Removed with air hammer and hand chipping	Steel sand blasted to white metal	None	After curing abutment sprayed with acrylic sealer - Cappar product "Niklepoxy Concrete Sealer 2M28".
Gardiner Expressway at Bathurst St.	East Face Bent 102	09/79	Latex modified shotcrete reinforced with galvanized wire	Removed with air hammer and hand chipping	Steel sand blasted to white metal	None	After curing bent sprayed with acrylic sealer - Cappar Product 2M Grey Niklepoxy.

Table 3/ Condition Survey Details

Site	Year Built	Test Date	Repair Date	Visual Condition	Half-Cell Test Percentage of Reading >-0.20 V -0.20 to -0.35 V <-0.36 V	Pachometer	Delaminations	Chloride Content
Hwy. 76 U.P./Hwy 401 #05123	1964	10/79	Not repaired	Staining and vertical cracking in splash zone	S.E. Column 6.3% 47.9% 45.8% Middle Column 87.5% 12.5% 0.0% S.W. Column 16.6% 47.9% 35.5%	35 mm to 60 mm cover	West Column: 50% delaminated Center Column: None East Column: 10% delaminated	0.20 mm 0.171% 40 - 60 mm 0.15% 80 - 100 mm 0.047%
		11/81	Not repaired	Staining and increased number of vertical cracks in splash zone	S.E. Column 4.2% 44.2% 51.6% Middle Column 79.1% 16.9% 0.0% S.W. Column 8.3% 39.6% 52.1%	No change	West Column: 75% delaminated Center Column: None East Column: 18% delaminated	Not retested (N.R.)
Bridge 21 Hwy 401/427 # 37816	1968	10/79	Not repaired	Isolated staining on abutment	0.0% 0.0% 100%* *52.4% <-0.51 V	80 mm to 100 mm cover	None	Variable results average 0-20 mm 0.4161% 40-60 mm 0.165% 80-100 mm 0.054% 120-140 mm 0.0265%
		06/81	Not repaired	No change	0.0% 0.0% 100%* *76.9% <-0.51 V	No change	None	N.R.
Bissette Creek Hwy 17 #29003	1961	09/81	09/79	Slight colour variation in patch	8.7% 67.3% 24%	Variable 23 to 68 mm cover	3% delaminated at edges of patch	Not Tested

Table 3/ Condition Survey Details (cont'd)

Site	Year Built	Test Date	Repair Date	Visual Condition	Half-Cell Test Percentage of Reading >-0.20 V	-0.20 to -0.35 V	<-0. 36V	Pachometer	Delaminations 40%	Chloride Content
Burlington Skyway/QEW # 36060 Column S-12	1957	10/79	10/79	Spall area 20% of column. 50% of spall patched with Set 45.	0.0%	41.4.1%	58.6%	70 mm to 100 mm cover	80% of colum west face delaminated	Variable 0-20 mm 0.2 to 0.1% 80-100 mm 0.075%
		06/80		Patch complete. Hair line cracks throughout	0.0%	31.5%	68.5%	No change (N.C.)	40% of patch delaminated. 50% of original delaminations still in place	Not Retested (N.R.)
		10/80		Small spall in patch. 72% of patch area. No change in cracks	0.0%	32.8%	67.2%	N.C.	N.C.	N.R.
		05/81		10% of patch spalled increase in the number of fine cracks	0.0%	24.3%	75.6%	N.C.	N.C.	N.R.
		09/81	06/81	New patch. slightly different colour	0.0%	48.6%	51.4%	N.C.	None	N.R.
Burlington Skyway # 36060 Column S-6	1957	10/79	05/80	2 small spalls, staining down column face	1.7%	70.5%	27.8%	80 to 150mm cover	6% of North face delaminated	Variable 0-20 mm 0.32% to 0.15% 60-80 mm 0.13% to 0.04%
		06/80		Patch slightly different colour	0.0%	52.8%	46.9%	N.C.	None. Removed during repair	N.R.
		10/80		No visible change	0.0%	54.6%	45.4%	N.C.	N.C.	N.R.
		05/81		No visible change	0.0%	46.3%	53.7%	N.C.	N.C.	N.R.

Table 3/ Condition Survey Details (cont'd)

Site	Year Built	Test Date	Repair Date	Visual Condition	Half-Cell Test Percentage of Reading >-0.20 V	-0.20 to -0.35 V	<-0.36 V	Pachometer	Delaminations	Chloride Content
Burlington Skyway # 36060 Column S-6	1957	09/81		Slight increase in staining	0.0%	50.4%	49.5%	N.C.	N.C.	N.R.
County Road 46 U.P. Hwy 401 #33177	1959	10/79	09/80	Severe spalling of columns in splash zone	75.1%	24.9%	0.0%	35 mm to 60 mm cover	5 to 10% delamination on each column	Variable 0-20 mm 0.09 to 0.2%
		09/81		Repair has slight colour variation	73.1%	26.9%	0.0%	No change (N.C.)	None	N.R.
Willey Sideroad U.P. Hwy 401 # 05047	1967	10/79	06/81	Staining and small spalls in splash zone	South East Column			45 mm to 60 mm cover	15-20% delamination on each column	10-40 mm 0.075% 60-80 mm 0.025% 100 mm 0.008%
					70.0%	17.5%	12.5%			
					South West Column					
					62.5%	20%	17.5%			
		11/81		Repair has slight colour variation	South East Column			N.C.	None	N.R.
					62.5%	32.5%	.5%			
					South West Column					
					62.5%	32.5%	.5%			
Gardiner Expressway Bent 102	1959	08/79	09/79	Widespread rust staining, cracking, spalling	15.3%	36.9%	47.8%	50 to 80 mm cover on pier cap. >125 mm on columns	Large areas on pier cap and middle column. Small areas on other columns.	Columns: 0-20 mm 0.13% to 0.32% 40-60 mm 0.08% to 0.26% Pier: 0-20 mm 0.21% 40-60 mm 0.13% 40-100 mm 0.05%

Table 3/ Condition Survey Details (cont'd)

Site	Year Built	Test Date	Repair Date	Visual Condition	Half-Cell Test Percentage of Reading >-0.20 V	-0.20 to -0.35 V	<-0.36 V	Pachometer	Delaminations	Chloride Content
Gardiner Expressway Bent 102	1959	10/79		Fine hairline random cracks exudation from some cracks	9.4%*	54.5%*	36.1%*	N.C.	None	N.R.
		06/80		No change in cracks staining due to joint leaks	7.0%*	52.0%*	40.9%*	N.C.	None	N.R.
		10/80		Increased staining	4.9%*	58.0%*	37.1%*	N.C.	None	N.R.
		06/81		Increased staining	17.3%*	31.5%*	51.2%*	No change (N.C.)	None	Not Retested (N.R.)
					* Half-cell readings affected by galvanized wire mesh will be more negative.					
Hwy 2 OP Hwy 401 Int. 31 # 23173	1955	10/79	07/81	Widespread rust staining, wide cracks, 12% west abutment spalled	0.0%	12%	88%	Variable cover Top: 10 mm Bottom: 150 mm	14% of abutment delaminated. Some multiple delaminations. Some delaminations in spalled areas	Variable Range 0-20 mm 0.47% to 0.203% 40-60 mm 0.197% to 0.038% 80-100mm 0.196% to 0.0239%
		09/81		Staining from leaky expansion joints. Moderate number random hairline cracks	0.0%*	16.3%*	83.7%*	Slight variation in repaired areas.	None	N.R.
					* Half-cell readings affected by galvanized wire mesh will be more negative.					

Figure 1/ Hwy. 76 – 1979 Condition

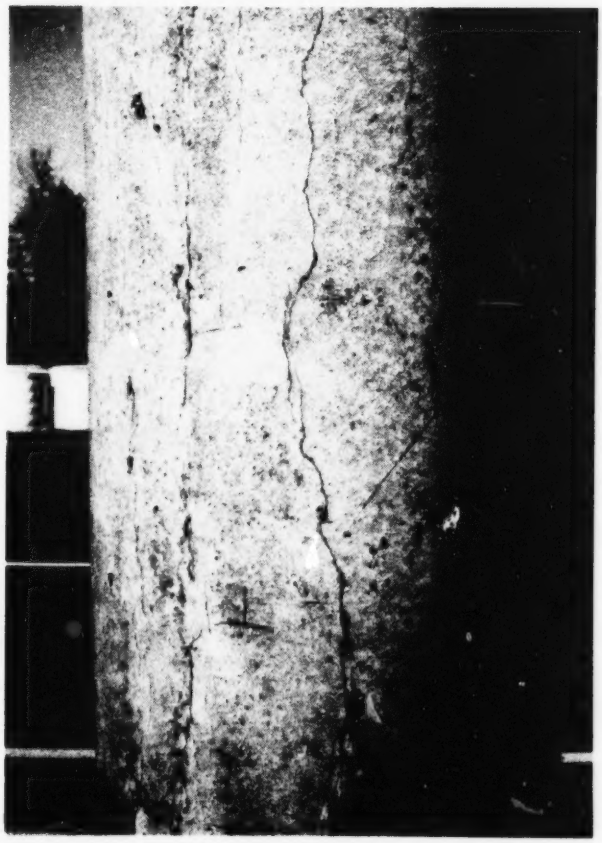

Figure 2/ Hwy. 76 – 1981 Condition

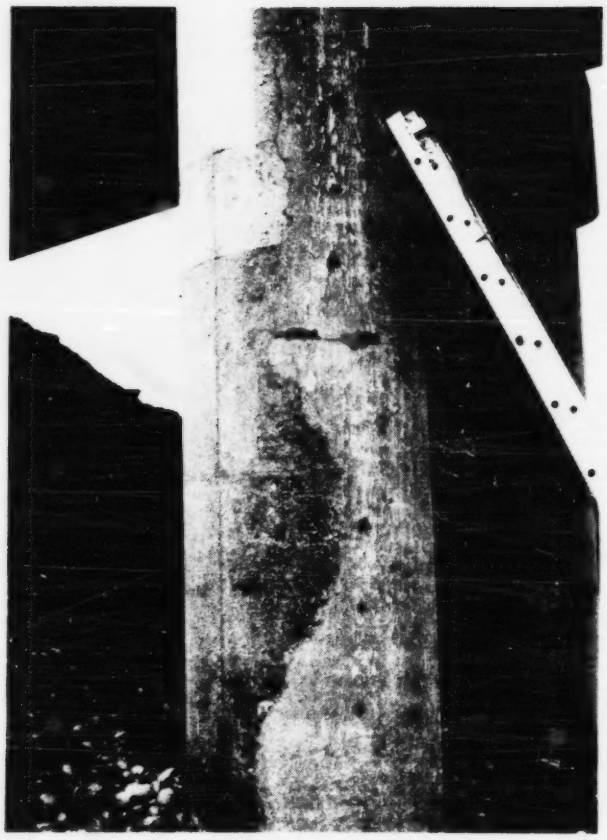

Figure 3/ Bissette Creek – Note Yellow Outline of Delaminations

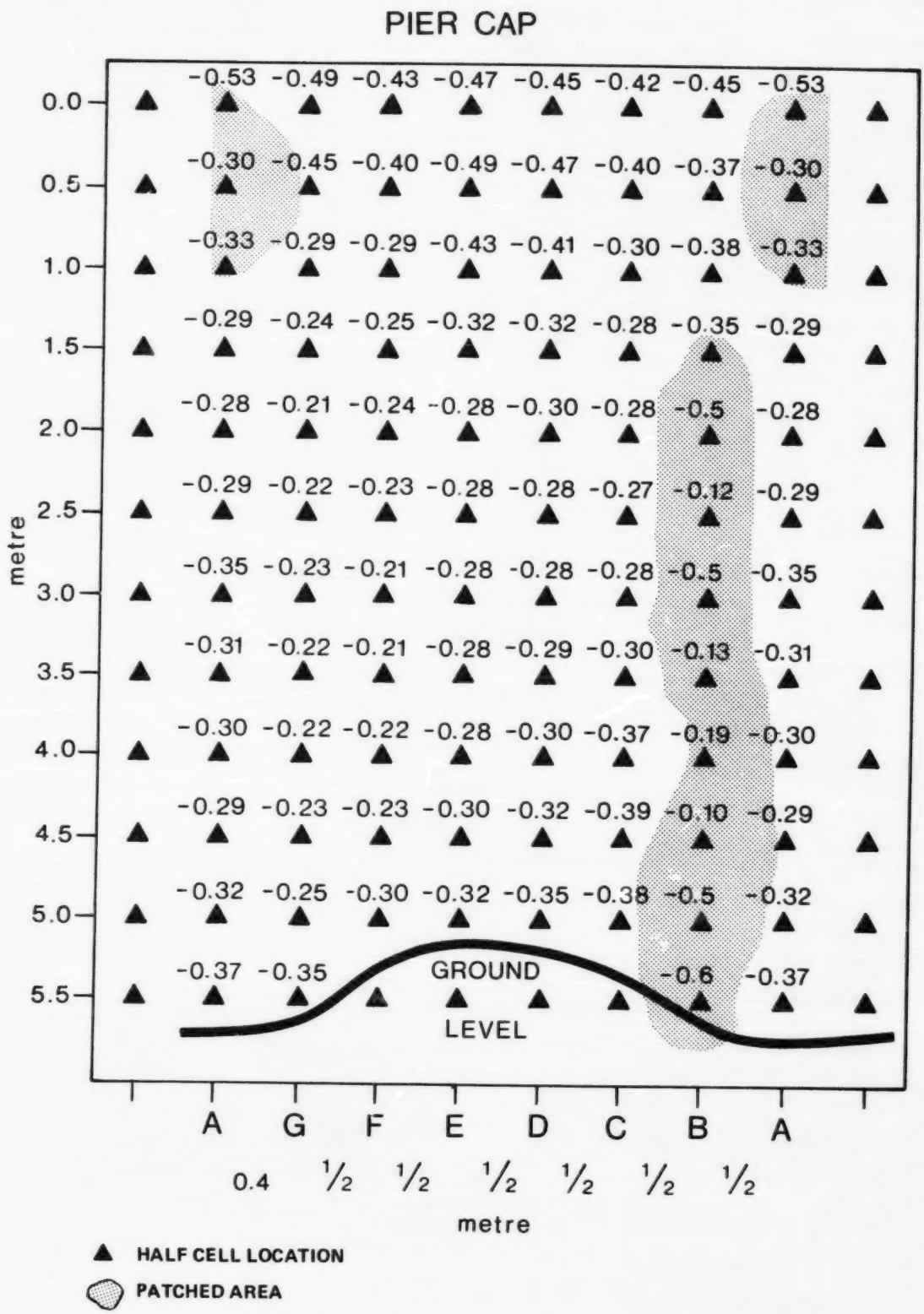

Figure 4/ Bissette Creek — 1/2 Cell Plot. Patch Area Shaded. Readings in Volts.

Figure 5/ Burlington S-12 – Partial Repair
Note Delaminations Marked in Yellow

Figure 6/ S-12 – Second Repair 1981

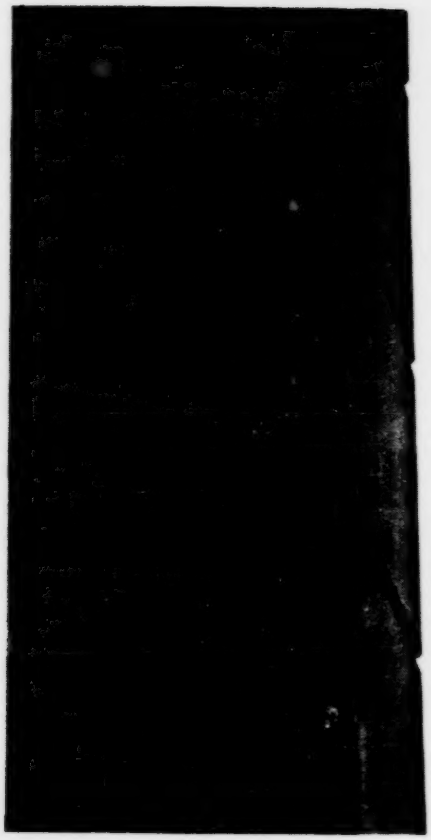

Figure 7/ S-6 – 1979 Condition

Figure 8/ S-6 – 1981 Condition
Note Unrepaired Section

Figure 9/ County Road 46 – 1979 Condition

Figure 10/ County Road 46 During Repair
Note Form

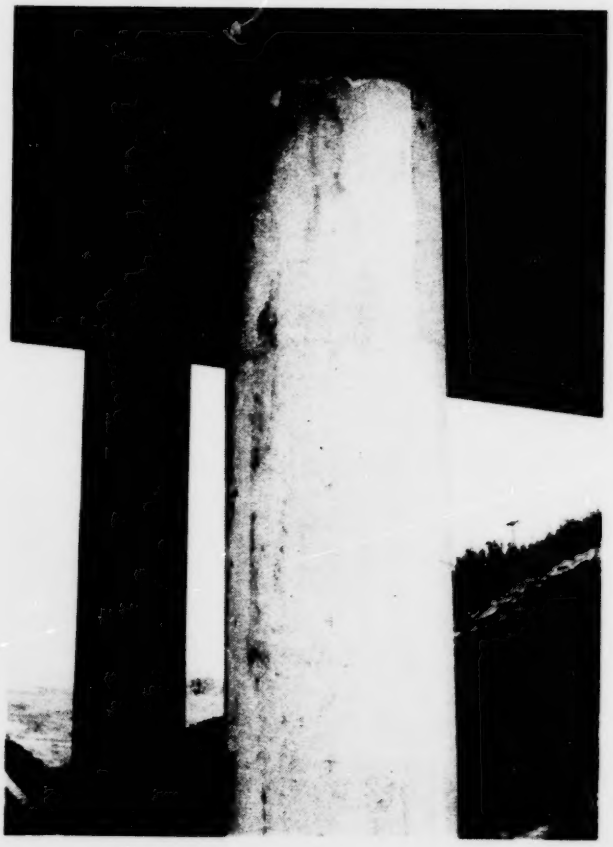

Figure 11/ County Road 46 – 1981 Condition

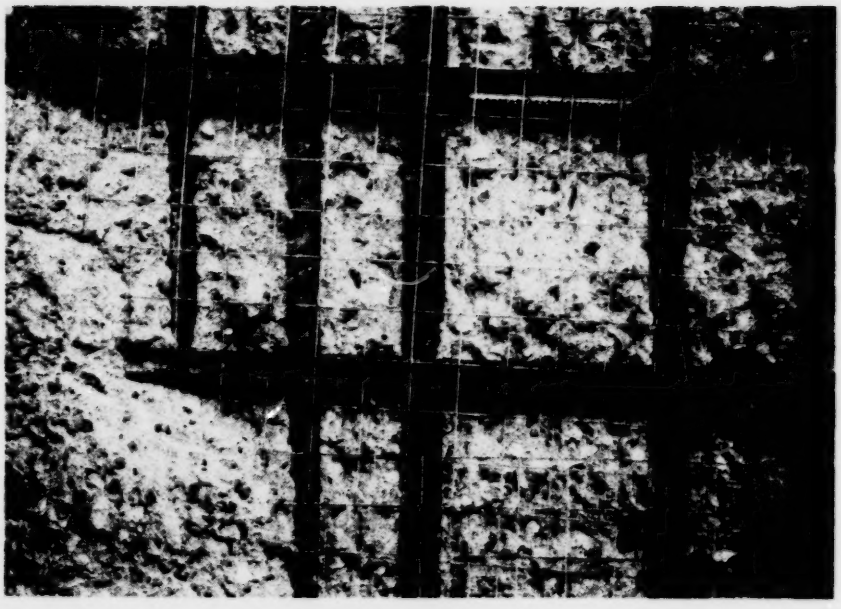

Figure 12/ Gardiner Expressway – Galvanized Mesh

Figure 13/ Gardiner Expressway – 1979 Condition

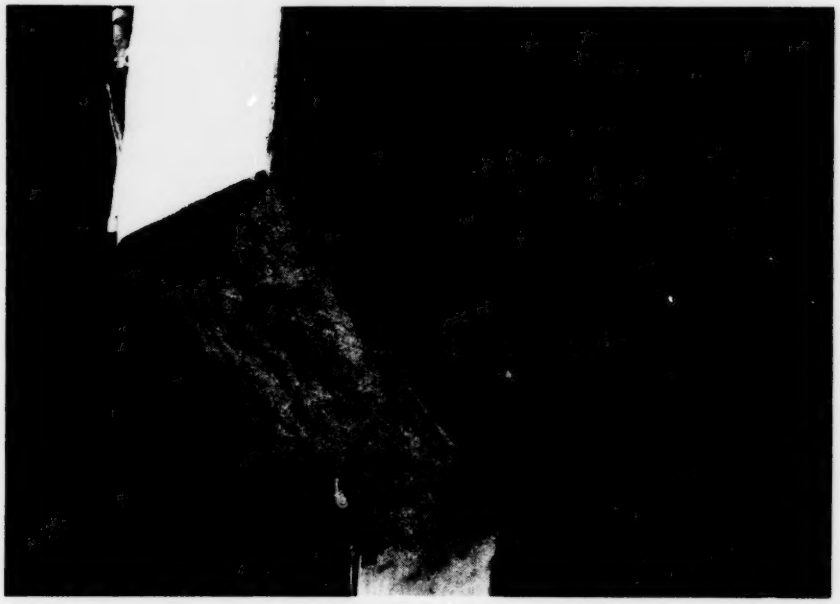

Figure 14/ Gardiner Expressway – 1981 Condition: Note Staining from Expansion Joint

Figure 15/ Hwy. 2/401 – 1979 Condition

Figure 16/ Hwy. 2/401 –1981 Condition: Note Staining from Expansion Joint Leaks

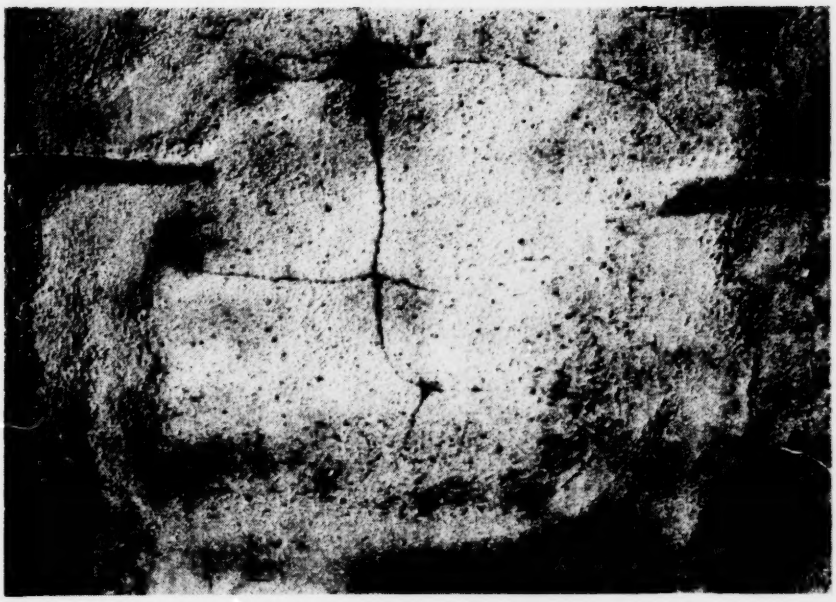

Figure 17/ Gardiner Expressway — Cracks in Shotcrete